Vibration Analysis of Alstom Typhoon Gas Turbine Power Plant Utility

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Abstract: Vibration analysis consider as one of the most important parameter in preventive maintenance. Gas turbine vibration analysis also consider as a most challenging category in most critical equipment monitoring systems in this paper first I tried to introduce vibration analysis for different type of equipment used in different industries. Then I will explain the most important tools and hypothesis used and analyzed for these kinds of activities through a real case history. The people who are not directly involve in this matters hope to have better understanding of most critical equipment vibration analysis and also I hope that the people who are directly work in preventive maintenance can touch with different aspect of gas turbine vibration analysis methodologies as well as possible.

Key words: Vibration analysis • Gas turbine • Time wave form (TWF) • Fast Fourier transform (FFT) • Phase angle • Orbit • Overall vibration • Bearing clearance • Unbalance • Signal Decomposition Technique • Bently Nevada panel

INTRODUCTION

Different maintenance strategies such as corrective maintenance, timebased, preventive maintenance, condition-based maintenance and predictive maintenance for different equipment developed in recent years. Human being speaks in different languages. When there is some sickness they could speak to the doctors and talk about the pains and discomfort but what is the machine language? Vibration is the machine language. The faults of machines like misalignment, unbalance, soft foot, bearing damage, high low and so on related to different parts of machine and each part have a unique frequency. Vibration analyst is a kind of translator of machine language in predictive maintenance. Some faults like misalignment, high low and soft foot consider as mother of others like bearing or gear damage and rotor touch. By translating this language we can predict these kind of high cost maintenance. Predictive maintenance developed in recent years because of such economic considerations [1]. In this part I try to introduce basic principal of vibration analysis. Data processing procedure base on measuring the vibration of machine with a transducer connected to a data collector or analyzer the best points for this purpose is bearings base on machine design process, that all of mechanical load of machine transfer to these parts. Also data collectors ability and software’s developed too much in recent years.

Figure 2 shows some typical data collector use in condition monitoring systems spectra pro is related software for easy viber and XMS is related software for vibro 60. time wave form (TWF) is the amplitude –time graph, fast Fourier transform (FFT) will draw by related software’s and condition monitoring techniques both FFT and TWF consider as main graphs in condition monitoring systems.

To achieve better understanding in both FFT and TWF I explain some examples. Imagine we have a rotor with small unbalance on the shaft and suppose that this machine have not any other faults or problems.

Now imagine this machine have a cooling fan for bearings or an impeller.

The frequency increase to 4X if X is equal to the rotational frequency of shaft in Figure 1. Now just imagine that this machine have a gear coupling and the gears have 12 teeth.
Fig. 1: Measuring machine vibration by transducer and data collector

Fig. 2: Typical data collector with their side facilities like piezoelectric transducers. up easy viber and down vibro 60

Fig. 3: TWF and FFT

The frequency increase to 12 X if X is equal to the rotational frequency of shaft in Figure 1. Now just imagine that we have all these part in a machine together.

In real industrial applications machines usually consist of several different parts, each parts have a unique frequency thus we have usually complex TWF.
But how we can decompose these kind of complex TWF in real application, if you remember the Fourier transform in mathematical engineering this will the key concept for these purpose in different data collectors and related software’s that help us to separates individual frequencies and then detects how much vibration exist at each frequency.

Now just come back to our machine that have 3 basic frequency thus this machine have theses all frequencies in its FFT then by monitoring these frequencies amplitude we can monitoring the condition of gear shaft unbalance and impeller separately.

Optimized Integrated Kurtosis-based Algorithm for Z-filter (I-kazTM) Coefficient using multilevel signal decomposition technique developed in recent years. The I-kazTM coefficient (Z) was originally developed base on the 2nd order of Daubechies signal decomposition. Higher order of I-kazTM coefficients, 3rd order (3Z), 4th order (4Z), 5th order (5Z), 6th order (6Z) and 7th order (7Z) were investigated by analyzing their response using two types of synthetic signals, TSA and TSB. The optimized order of I-kaz Multi Level coefficient was chosen base on the sensitiveness of the coefficient response with respect to the changes of amplitude in TSA and frequency in TSB synthetic signals. To simplifying the process Consider a typical dynamic signal as illustrated in Figure 11. The decomposition of the signal in the time domain was done by considering the 2 order of the Daubechies concept in signal decomposition process [2].

The software’s have some facilities like cursor that can calculate these frequency accurately and compare them with the previous FFT condition of the machine each part have a unique frequency and by monitoring these frequencies we can achieve the condition of each machine component separately and accurately.
Fig. 11: The decomposition process of a signal in I-kaz procedure

Fig. 12: General fault diagnosis typical diagram.

Trend of overall frequencies and vibration spectrum provide useful information to analyze defects in roller bearings. Trend indicates severity of vibration in defective bearings. Vibration domain spectrum identifies amplitudes corresponding to defect frequencies and enables to predict presence of defects on inner race and outer race of roller bearings. The distinct and different behavior of vibration signals from bearings with inner race defect and outer race defect helps in identifying the defects in roller bearings. Several frequency exist in ball bearings inner race, outer race, cage, ball rotational and ball travel frequency can all detected by software in FFT by adding the bearing code number and types to the software for each point in initial monitoring situation. The software will calculate all frequencies automatically [3].

1X generally related to faults like unbalance, bent shaft, misalignment and soft foot because these faults amplify by main rotational shaft speed the phase analysis may help us to distinguish the different characteristics of these faults and help us to diagnose the machine fault correctly. 2x also may related to misalignment or soft foot, 3x amplified by mechanical or rotary looseness's. High frequencies vibrations also may cause by some gear or bearing problems (between 1000 to 20000 Hz) these diagrams just introduce general view to achieve better understanding of vibration analysis in machine fault diagnosis in real application professional software’s help us to analyze the machine vibration with FFT and other types of machine vibration graphs and also monitoring techniques there are also some global standard for overall bearings inner race, outer race, cage, ball rotational and vibration alert and danger limits for different type of ball travel frequency can all detected by software in FFT equipment usually base on machine KW and also types of machine foundation like rigid and flexible foundations beside this vibration history of machine play a big role to such vibration limits definition in all fields in preventive maintenance nowadays data collector software’s have different types of facilities that can help us to monitoring special band frequencies in FFT for any further fault diagnosis applications [4].
Experimental Detail: Alstom typhoon gas turbine is a kind of utility in our plant. And have an important role in process. Therefore it is a kind of most critical equipment. TWF, orbit and phase analysis all are important factors in gas turbine vibration analysis beside FFT. In this part I will try to explain the vibration monitoring system of this gas turbine and also I will explain all key important elements in gas turbine vibration analysis mentioned before the gas turbine equipped with bently Nevada on line monitoring system the system based on non-contact probe who monitoring the shaft vibration usually in micrometer peak to peak. The overall vibration have some limitation standard for each equipment that adjust for alert and danger condition in fair condition (passing the alert limit) the alarm lamp will indicate close monitoring condition and by passing danger limit the gas turbine will trip to prevent harmful damages in machine the bently Nevada main board equipped with some bently Nevada connections for mentioned data collector like easy viber that help us monitor FFT, TWF and phase values the system also equipped with overall vibration monitoring in process system beside process conditions like inlet and outlet pressures and temperatures.

Wireless condition monitoring system developed in recent years for most critical equipment like gas turbine the advantages of these kind of systems is reduce the special tools installation errors as well as possible also the accuracy and speed of these kind of monitoring system is much better than conventional portable systems the disadvantages of these kind of systems is high cost of them. [6, 7, 8, 9] Nowadays TWF vibration analysis plays a big role in preventive maintenance specially in most critical equipment like gas turbines. Now I try to explain basic principal of TWF vibration analysis. The time wave form analysis usually complex in industrial equipment but sometimes have some simple academic shapes that could easily represented some main faults in machine otherwise we should compare these kind of graphs with machine history and compare the changes accurately by different cursors and facilities in nowadays software’s. there is some limitation in FFT analysis in such cases TWF analysis will help a lot. The TWF analysis should be effective in some fields like, Low speed applications (less than 100 RPM), Indication of true amplitude in phase elements and help us a lot to realizing the gas turbine vibration process by trigger (usually) 1X frequency FFT by a key phase and related reflector system on main shafts. In none critical equipment it can help us to trigger some remind phases in FFT like unbalance, soft foot, bent shaft and misalignment. Beside this it is the key factor to diagnosis the high low flange and also mechanical looseness. In most critical equipment phase analysis is a key element specially in run up, coast down and bode diagrams that all base on phase elements and help us a lot to realizing the gas turbine or any other most critical equipment condition. These kind of techniques will help us in some complex fault diagnosis process like shaft crack in most critical equipment. Unbalance considering as one of major faults that may occur in different rotary part of machine like main
rotor or coupling the coupling unbalance is more difficult to diagnosis because of interfering the misalignment characteristic with unbalance characteristic both in TWF and FFT. The phase analysis could help us a lot in these kind of condition to distinguish between these two main coupling faults. [11] shaft crack also consider as one of important faults in all most critical equipment and also gas turbines. This fault is usually hard to diagnosis. Shaft crack may be longitudinal or radial and it may have some microscopic dimensions. The none contact probe may detect wrong or fake data, alert, trip, TWF and orbit because of these kind of microscopic crack. These kind of crack will disappear by metal spray in maintenance activities [12] having optimum understanding of process parameter trend of all most critical equipment always play an important role in vibration analysis. nowadays many methods developed in modeling processing condition of such equipment. systematic analysis of two-stage, axial flow turbine by using of different losses models and a new suggested algorithm based on one-dimensional simulation. The suggested method is found to be effective, fast and stable, in obtaining performance characteristics of multi-stage axial flow turbines. In one-dimensional modeling, mass flow rate, pressure ratio and efficiency are unknown, with define turbine geometry, inlet total pressure and
Fig. 18: Unbalance rotor TWF

Fig. 19: High frequency TWF

Fig. 20: Classical misalignment TWF

Fig. 21: Typical classic rotor rub TWF

Fig. 22: Typical classic Beats & Modulation effects in TWF
temperature the turbine performance characteristics can be modeled. This modeling is based on common thermodynamics and aerodynamics principles in a mean stream line analysis under steady state condition [13]. Many vibration environments are not related to a specific driving frequency and may have input from multiple sources which may not be harmonically related. Examples may be excited from turbulent flow as in air flow over a wing or past a car body, or acoustic input from jet engine exhaust, wheels running over a road, etc. With these types of vibration, it may be more accurate, or interested to analyze and tested using random vibration. Unlike sinusoidal vibration, acceleration, velocity and displacement are not directly related by any specific frequency. Of primary concern in random testing is the complete spectral content of the vibration being measured or generated. Most random vibration testing is conducted using Gaussian random suppositions for both measurement and specification purposes. With Gaussian assumptions, there is no definable maximum amplitude and the amplitude levels are measured in RMS (root-mean-squared) values. On the other hand in low frequency applications like reciprocating compressor data usually measured by peak to peak. The on line monitoring rod drop system also available for such most critical equipment also vibration analysis could be extremely useful for mechanical part of electro motor or generators fault diagnosis. (like all kind of bearings or gear couplings) [14]. The machine foundation condition is also one of the basic principal in preventive maintenance as well as machine installation. There are two kind of machine foundation, flexible and rigid. Type of foundation have a direct role in vibration standard of machine. Soft foot, mechanical looseness and foundation problem could diagnosed by phase analysis in preventive maintenance. Nowadays some kind of data collector and related soft wares developed for vibration modal analysis that could help us a lot in foundation problem diagnosis (like VDAU-6000 condition monitoring system). The foundation design techniques also developed too much in recent years. Damping is a complex phenomenon which acts in the form of absorption and dissipation of the energy in the vibrational systems. Different factors effect on the damping such as type of joints in the connections. Also more effective and efficient shock absorber designed in recent years that reduce the machine vibrations specially in some critical location like air cooling and cooling tower fans [15]. Also the effect of different machine and process parameter on the main rotor or shaft natural frequency of all most critical equipment widely investigated in recent years and nowadays we have better understanding of such matter in most critical equipment. Such fault diagnosis usually more effective in startup and shut down machine trend parameter. (Coast down and run up characteristics or bode diagram) [16].

**RESULT AND DISCUSSION**

All gas turbines utility system consist of five main parts, basic gas turbine, air compressor, air preheater, combustion chamber and generator. Inlet and outlet pressure and temperature consider as main critical process parameter in all gas turbine systems [17].

In this part I will explain a case history related to a gas turbine Alstom typhoon in oil industries. All critical process parameter trends was on the range of technical document of gas turbine and in normal condition and The overall vibration data on bently Nevada main board increased too much but not overflowing the vibration ranges. The arrow show the direction of this increasing in bently Nevada panel at Sunday, July 8, 2012.
Fig. 24: Gas turbine system

Fig. 25: Bently Nevada panel before vibration analysis process

Fig. 26: Regular periodic rubs in NDE driven unit bearings

Fig. 27: Rub in NDE driven unit bearings orbit
The TWF and related orbit of NDE driven unit bearings show that there are some rub in this point and it should be analyzing the oil sample in this point. The oil analysis report confirm this phenomena. Thus we first strongly recommended check the bearing clearances in this point.

Also drive end unit bearings TWF and FFT representing the dynamic unbalance in this point (comparative to previous TWF and FFT in this point).

Also we recommended operate dynamic balance process after static balance. These kind of field balance process consist of accurate try and error balancing process and adding suitable balancing weights in correct directions in panel 2.

After balancing process and check the bearing clearances the overall vibration decrease considerably specially in unbalance point. The vibration conditions come back to previous status and the vibration analysis was successful.

**CONCLUSION**

In gas turbine vibration analysis we should have good monitoring data bank like overall vibration, FFT, TWF, orbit and also phase values. By comparing the data we can achieve the optimum recommendation in this matter. it is also important to have a suitable understanding of process conditions like inlet and outlet pressure and temperatures to analysis some aspect of TWF behaviors also we should always connected to other condition monitoring groups in different parts of world and industries to updates ourselves with new
patent and innovation in monitoring systems and also developed and optimized vibration monitoring and analysis techniques and evaluations.

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